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Does active mobility reduce the likelihood of depression? Cross-sectional study in three Brazilian cities

A mobilidade ativa reduz a probabilidade de depressão? Estudo transversal em três cidades Brasileiras

¿Reduce la movilidad activa la probabilidad de depresión? Un estudio transversal en tres ciudades brasileñas

Danúbia Hillesheim https://orcid.org/0000-0003-0600-4072 [1]; Ingrid Luiza Neto https://orcid.org/0000-0001-8177-8823 [2]; Hartmut Günther https://orcid.org/0000-0002-9483-7615 [3]; Júlio Celso Borello Vargas https://orcid.org/0000-0001-8321-5362 [4]; Tim Jones https://orcid.org/0000-0002-5187-5654 [5]; Eleonora d'Orsi https://orcid.org/0000-0003-2027-1089 [6]

Abstract *This study aimed to estimate the association between commuting by different modes of transport and self-reported depression among adults and older adults in three Brazilian cities. This is an observational study with a cross-sectional design, utilizing data from the household survey of the Healthy Urban Mobility (HUM) Project (2017-2018). The dependent variable was self-reported depression, and the independent variables were related to the different modes of transport used. In total, 3,296 individuals participated in the study, 1,107 in Brasília, 1,084 in Florianópolis, and 1,105 in Porto Alegre. Using bicycles was a protective factor for depression in Porto Alegre. On the other hand, using the subway/train increased the chances of depression in Brasília. Those who simultaneously rode bus/van and subway/train, and car/taxi and subway/train, were more likely to report depression in Brasília. In conclusion, this study found an association between commuting modes and self-reported depression. Cycling in Porto Alegre served as a protective factor, while non-active transportation increased the likelihood of depression in Brasília. These results highlight the need to promote active commuting as a public health strategy.*
Key words *Active Mobility, Modes of Transport, Depression, Commuting, Mental Health*

Resumo *Este estudo teve como objetivo estimar a associação entre o deslocamento por diferentes meios de transporte e a depressão autorreferida entre adultos e idosos em três cidades brasileiras. Trata-se de um estudo observacional com desenho transversal utilizando dados da pesquisa domiciliar do Projeto Mobilidade Urbana Saudável (MUS) (2017-2018). A variável dependente foi a depressão autorreferida, e as variáveis independentes estavam relacionadas aos diferentes meios de transporte utilizados. No total, 3.296 indivíduos participaram do estudo, sendo 1.107 em Brasília, 1.084 em Florianópolis e 1.105 em Porto Alegre. O uso de bicicleta foi um fator protetor contra a depressão em Porto Alegre. Por outro lado, o uso do metrô/trem aumentou as chances de depressão em Brasília. Aqueles que utilizaram simultaneamente ônibus/van e metrô/trem, e carro/táxi e metrô/trem, foram mais propensos a relatar depressão em Brasília. Em conclusão, este estudo encontrou uma associação entre os meios de transporte e a depressão autorreferida. O uso da bicicleta em Porto Alegre atuou como um fator protetor, enquanto o transporte não ativo aumentou a probabilidade de depressão em Brasília. Esses resultados destacam a necessidade de promover o deslocamento ativo como uma estratégia de saúde pública.*
Palavras-chave *Mobilidade Ativa, Meios de Transporte, Depressão, Deslocamento, Saúde Mental*

Resumen *Este estudio tuvo como objetivo estimar la asociación entre el desplazamiento en diferentes modos de transporte y la depresión autoinformada entre adultos y adultos mayores en tres ciudades brasileñas. Se trata de un estudio observacional con un diseño transversal que utilizó datos de la encuesta de hogares del Proyecto de Movilidad Urbana Saludable (MUS) (2017-2018). La variable dependiente fue la depresión autoinformada y las variables independientes se relacionaron con los diferentes modos de transporte utilizados. En total, 3296 personas participaron en el estudio: 1107 en Brasilia, 1084 en Florianópolis y 1105 en Porto Alegre. El uso de la bicicleta fue un factor protector contra la depresión en Porto Alegre. Por otro lado, el uso del metro/tren aumentó la probabilidad de depresión en Brasilia. Quienes usaron simultáneamente autobús/furgoneta y metro/tren, y coche/taxi y metro/tren, tuvieron mayor probabilidad de reportar depresión en Brasilia. En conclusión, este estudio encontró una asociación entre los medios de transporte y la depresión autoreportada. El uso de la bicicleta en Porto Alegre actuó como factor protector, mientras que el transporte no activo aumentó la probabilidad de depresión en Brasilia. Estos resultados resaltan la necesidad de promover el desplazamiento activo como estrategia de salud pública.*
Palabras clave *Movilidad activa, Medios de transporte, Depresión, Desplazamiento, Salud mental*

[1] Programa de Pós-Graduação em Ciências Médicas, Universidade Federal de Santa Catarina. R. Delfino Conti s/n, Campus Reitor João David Ferreira Lima, Bloco H. 88040-900 Florianópolis SC Brasil. nubiah12@yahoo.com.br
[2] Universidade Católica de Brasília. Brasília DF Brasil.
[3] Departamento de Psicologia Social e do Trabalho, Universidade de Brasília. Brasília DF Brasil.
[4] Departamento de Urbanismo, Universidade Federal do Rio Grande do Sul. Porto Alegre RS Brasil.
[5] School of the Built Environment, Faculty of Technology, Design, and Environment, Oxford Brookes University. Oxford UK.
[6] Departamento de Saúde Pública, Universidade Federal de Santa Catarina. Florianópolis SC Brasil.

Introduction

Urban planning plays a key role in addressing health challenges of the 21st century[1]. Transport planning plays a fundamental role in the construction of cities that boost beneficial results for the health and well-being of the population[2].

The Sustainable Urban Mobility Plan (SUMP), established by the European Commission (EC) in 2013[3,4], recommended that European locations implement sustainable urban mobility plans to improve the urban environment and quality of life of residents, focusing on the most vulnerable users of public roads: pedestrians and cyclists[3]. Subsequently, in large European cities such as London, Barcelona, and Paris, measures were implemented to transform roads into environments conducive to the well-being of citizens, including a more significant presence of green areas and the encouragement of active mobility[5].

In this context, the Sustainable Development Goals (SDGs), launched in 2015 by the United Nations (UN) in the 2030 agenda, aim to make cities more inclusive, safe, and sustainable, including improvements in transport systems. However, a 2023 UN report reinforced the urgency of improving the quality and accessibility of transport infrastructure globally, especially in developing countries[6]. The report emphasized the need to integrate motorized transport with walking and cycling through sustainable urban mobility plans and effective policies. However, in Brazil, less than 1% of the SDGs have satisfactory progress until 2030[7,8].

Although the Brazilian Law No. 12,587/2012[9] established the guidelines of the National Urban Mobility Policy (PNMU), highlighting the priority of non-motorized modes of transport over motorized ones, few efforts have been concentrated on changing this scenario in the country. From 2005 to 2015, the number of motor vehicles increased 138% in Brazil. In contrast, the population grew 12.2%[10]. Data from the 2022 Brazilian Urban Mobility Survey (PBMU) showed that in the capitals individuals spend, on average, 21 days a year in traffic[11]. There is a widespread perception that this scenario will persist, since policies to stimulate the production, sale, and use of private vehicles predominate over measures promoting the use of public and non-motorized transport[12].

Researchers have shown that congested traffic, long travel times, poor public transport conditions, and even excessive dependence on private cars can generate stress, excessive noise, and negative impacts in well-being, including the occurrence of depression[13-15]. According to a 2017 report from the World Health Organization[16], depression is the leading global cause of disability, impacting approximately 322 million people worldwide—equivalent to 4.4% of the population—with higher rates among women. In Brazil, the 2019 National Health Survey (PNS) found that about 10.2% of adults aged 18 and older had been diagnosed with depression, up from 7.6% in 2013, underlining an escalating public health concern[17].

In contrast, a public transport system with good connectivity, comfort, and short time travel reduces traffic accidents and pollutant emissions, increases physical fitness, and improves mental health[18]. Regarding active mobility, such as walking and cycling, European and North American studies have shown that these modes are associated with better mental health outcomes due to the physical and psychological benefits they provide[2,19-23]. Although these associations have been investigated in different cities, the Brazilian context is understudied. Brazil has unique urban challenges, being crucial to analyze differences in passengers' experience while interacting with different modes of transport. It is also essential to better understand the relationship between modes of transport and depression in Brazilian cities to guide public policies and interventions that promote the health and well-being of individuals.

Given this context, this study aimed to estimate the association between commuting by different modes of transport and self-reported depression among adults and older adults in three Brazilian cities.

Methods

Study design

This paper presents an observational epidemiological study with a cross-sectional design, utilizing data from the household survey conducted within the 'Healthy Urban Mobility' (HUM) study (2017-2018). The HUM study investigated associations between the built environment, travel behavior, and health/wellbeing of residents in various urban areas across three Brazilian capital cities. Data collection was conducted in three Brazilian cities (Brasília, Florianópolis, and Porto Alegre), chosen considering

their spatial and demographic characteristics as well as their challenges in promoting healthy urban mobility.

In each city, three neighborhoods were selected to integrate the study, respecting the following inclusion criteria: (a) distance to the downtown area of less than 10 km; (b) homogeneous socioeconomic condition; (c) type of urban fabric - designed or informal, according to the pattern of the road layout. Thus, data collection took place in three areas per city: two with household income up to the second quintile of the distribution - one of them informal and the other designed - and a third area with income up to the fourth quintile. After applying these criteria, the following neighborhoods were included in the study: Saco Grande, Jardim Atlântico, and Costeira do Pirajubaé in Florianópolis; Varjão, Vila Planalto, and SQN 409/410 in Brasília; Cruzeiro, Menino Deus, and Tronco in Porto Alegre.

Sampling and data collection

The data collection period was between May 2017 and June 2018. Regarding the calculation of the sample of households in Florianópolis and Porto Alegre, after identifying the total number of addresses registered in each study area with the official agencies (IBGE, National Register of Addresses for Statistical Purposes - CNEFE, Geoportal), a 95% confidence level and a confidence interval of ±5% were used, adopting, as a universe, the total number of households located in the polygons corresponding to each area. Random sampling was performed using the non-spatial "subset" method in ArcGIS 10.2.2 software. This technique divides the data (the total addresses in the list) into two subgroups: the first has L addresses, and the second has N - L, where L equals 500, and N is the total number of addresses in the universe. This division generates random values from an uniform distribution (values between 0 and 1). If the generated value is less than L/N, it is allocated in the first subset. If not, it is allocated in the second one. Moreover, OpenEpi was used to calculate the power of the study, obtaining the power of 100% for this research.

In Brasília, sampling was defined by simple random selection from the general list of addresses, selecting 500 residences using the IBM SPSS software. However, in one of the neighborhoods, we opted to use the snowball technique due to situations of violence and unsafety experienced by the researchers when visiting the previously selected addresses. The snowball technique is a non-probabilistic sample method that uses reference chains.

Adults and older adults over 18 years of age residing in the three Brazilian cities were included in this research. Bedriddens, pregnants and individuals with some limiting mental disability perceived by the interviewer at the time of the interview were excluded from the survey. For data collection, properly trained interviewers applied a standardized and pre-tested questionnaire during on-site interviews. The questionnaire was programmed on the Android operating system, on a tablet model M9 QUAD Multilaser by a specialized technician. The consistency of the data was checked weekly, and the reliability was controlled via telephone by checking the questionnaire responses with 10% of the participants, randomly selected.

Dependent variable

The dependent variable in this study was self-reported depression, attested if any doctor or health professional has ever said that the participant has or had depression. Despite its subjective character, self-reported depression is widely used in population-based studies[17,24] and was validated in a Brazilian cohort study, with sensitivity and specificity of 80.6% and 81.4%, respectively[25].

Independent variables

The independent variables were related to the modes of transport used by adult and older adult participants, derived from the *Impact of Constructing Non-motorised Networks and Evaluating Changes in Travel* (iConnect) instrument[26]. Participants were instructed to indicate modes of transport used during last week, regardless of the time and reason for leaving home. The questions asked were: "*In the last week, did you leave the house by walking?*"; "*In the last week, did you leave the house by bus or van?*"; "*In the last week, did you leave the house by subway/train?*"; "*In the last week, did you leave the house by car or taxi as a driver?*"; "*In the last week, did you leave the house by car or taxi as a passenger?*"; "*In the last week, did you leave the house on a motorcycle?*". The following question was used to measure bicycle use: "*Do you currently cycle?*". The variable "car and/or taxi" was grouped for analysis purposes, includ-

ing individuals who left home by car and/or taxi as a driver and/or passenger. All the questions were dichotomic, ("no" and "yes").

Covariates

In line with previous researchers[15], sociodemographic control variables were utilized. The analyses were adjusted for the following sociodemographic variables: sex (male; female), age in categories (18 to 29; 30 to 39; 40 to 49; 50 to 59; 60 to 69; 70 to 79; 80 or more), education in complete years of schooling (0 to 4 years; 5 to 11 years; 12 years or more), and race/skin color (white; brown; black; yellow; indigenous).

Data analysis

Initially, a descriptive analysis of all variables was performed by calculating absolute and relative frequencies with respective 95% Confidence Intervals (95%CI). The prevalence of self-reported depression was estimated according to the independent and covariate variables, using Pearson's chi-square test to compare the proportions. When the assumptions of the chi-square test were not met, Fisher's exact test was used. The analyses were stratified by city (Brasília, Florianópolis, and Porto Alegre).

For both the crude (bivariate) and adjusted analysis, the odds ratio (OR) was used to measure association, estimated through Logistic Regression analysis. The variables were included simultaneously in the analysis and adjusted for each mode using the *enter* method. Interaction analyses were conducted to investigate the effect of the simultaneous use of different modes of transport on the research outcome. Post-estimation analyses were conducted to verify whether the models built had explanatory potential, using Hosmer-Lemeshow test ($p>0.050$). All results found were adequate. Data analysis was conducted using Stata statistical software version 14.0 (https://www.stata.com), and the results were considered statistically significant ($p<0.05$).

Ethical Aspects

The Research Ethics Committee of Universidade de Brasília (UnB) (November 16, 2016) approved the project under protocol number 1.831.179 and CAEE: 58214416.9.1001.0030. All research participants signed the Informed Consent Form (ICF) before data collection.

Results

In total, 3,296 individuals were interviewed in the three cities, 1,107 in Brasília, 1,084 in Florianópolis, and 1,105 in Porto Alegre. Most of the sample was female (>60.0%), with age ranging from 18 to 29 years old in Brasília (29.2%) and Porto Alegre (19.4%) and from 60 to 69 years old in Florianópolis (22.6%). Regarding education, 42.0% of all respondents had 12 or more years of schooling, highlighting the city of Brasília, whose percentage reached 52.7% for this category (Table 1).

Regarding dependent variable, depression was self-reported by 16.6% of the total sample, 15.0% in Brasília, 16.3% in Florianópolis, and 18.6% in Porto Alegre. Walking was the most prevalent mobility mode among the interviewees in all the cities analyzed (Table 1).

In Table 2, there was a higher prevalence of depression among those who did not use bicycles for transport in Brasília (17.1%), Florianópolis (17.6%), and Porto Alegre (20.7%) when compared to those who used them. This difference was statistically significant ($p<0.001$) (Table 2).

In the crude analysis, the use of bicycles was a protective factor for self-reported depression in all the three cities, with a statistically significant association (Table 3). In Brasília, those who used bicycles as a modes of transport were 37% (OR: 0.63; 95%CI: 0.44-0.91) less likely to report depression than those who did not use it (<0.001). Similar results were observed in Florianópolis (OR: 0.51; 95%CI: 0.31-0.85) and Porto Alegre (OR: 0.47; 95%CI: 0.30-0.74) (Table 3).

In the final adjusted analysis, bicycle use remained a protective factor for depression in all cities surveyed, but it was statistically significant only in Porto Alegre (OR: 0.60; 95%CI: 0.37-0.97). Also, using the subway/train increased the probability of reporting depression in Brasília (OR: 1.62; 95%CI: 1.01-2.62) (Table 4).

When analyzing the simultaneous use of motorized and active modes of transport, those who rode bus/van and subway/train in Brasília were 1.76 times more likely to report depression than individuals who did not use it ($p=0.037$). The same was observed for individuals who rode car/taxi and subway/train (OR: 2.19; 95%CI: 1.07-4.48), with a 119% increase in the probability of depression. Except for Brasília, walking and cycling remained a protective factor for depression, although there was no statistically significant association (Table 5).

Table 1. Description of sociodemographic characteristics, modes of transport, and self-reported depression. Healthy Urban Mobility (HUM) Study, Brasília, Florianópolis, and Porto Alegre, Brazil, 2023.

Variable n (%)	Brasília (n=1,107)		Florianópolis (n=1,084)		Porto Alegre (n=1,105)	
	CI95%	n (%)	CI95%	n (%)	CI95%	
Sex						
Male	398 (35.9)	33.1-38.8	328 (30.3)	27.5-33.0	374 (33.8)	31.1-36.6
Female	709 (64.1)	61.1-66.8	756 (69.7)	66.9-72.4	731 (66.2)	63.3-68.8
Age						
18 to 29	323 (29.2)	26.5-31.9	105 (9.7)	8.0-11.5	214 (19.4)	17.7-21.8
30 to 39	226 (20.4)	18.1-22.8	124 (11.4)	9.6-13.4	182 (16.5)	14.4-18.8
40 to 49	209 (18.9)	16.6-21.2	180 (16.6)	14.5-18.9	160 (14.5)	12.5-16.7
50 to 59	179 (16.2)	14.1-18.4	242 (22.3)	19.9-24.9	206 (18.7)	16.4-21.0
60 to 69	102 (9.2)	7.6-11.0	245 (22.6)	10.2-25.1	194 (17.6)	15.4-19.9
70 to 79	49 (4.4)	3.3-5.8	139 (12.8)	10.9-14.9	111 (10.0)	8.4-11.9
80 or more	19 (1.7)	1.0-2.6	49 (4.5)	3.4-5.9	36 (3.3)	2.3-4.4
Education						
0 to 4 years	115 (10.4)	8.7-12.3	230 (21.2)	18.8-23.7	228 (20.6)	18.3-23.1
5 to 11 years	407 (36.9)	34.0-39.7	506 (46.7)	43.7-49.6	424 (38.4)	35.5-41.2
12 years or more	281 (52.7)	49.7-55.6	348 (32.1)	29.3-34.9	453 (41.0)	38.1-43.9
Race/skin color						
White	327 (30.3)	27.6-33.1	863 (79.7)	77.1-81.9	692 (63.3)	60.3-66.0
Mixed-race	499 (46.3)	43.2-49.2	134 (12.4)	10.5-14.4	186 (17.0)	14.8-19.3
Black	204 (18.9)	16.6-21.3	81 (7.5)	6.0-9.2	193 (17.6)	15.4-20.0
Yellow	33 (3.0)	2.1-4.2	1 (0.0)	0.0-0.6	7 (0.6)	0.3-1.3
Indigenous	16 (1.5)	0.9-2.4	4 (0.4)	0.0-0.9	16 (1.5)	0.8-2.3
Depression						
No	933 (85.0)	82.8-87.0	900 (83.7)	81.3-85.1	886 (81.4)	79.0-83.6
Yes	164 (15.0)	12.9-17.1	175 (16.3)	14.1-18.6	202 (18.6)	16.3-20.9
Bicycle						
No	676 (61.3)	58.3-64.1	894 (82.5)	80.0-84.6	868 (79.1)	76.6-81.4
Yes	427 (38.7)	35.8-41.6	190 (17.5)	15.3-19.9	229 (20.9)	18.5-23.3
Walking						
No	198 (17.9)	15.7-20.3	384 (35.4)	32.6-38.3	258 (23.5)	21.0-26.1
Yes	905 (82.1)	79.6-84.2	700 (64.6)	61.1-67.3	839 (76.5)	73.8-78.9
Bus or van						
No	577 (52.5)	49.5-55.4	596 (55.0)	52.1-58.0	470 (43.0)	40.1-46.0
Yes	522 (47.5)	44.5-50.4	486 (45.0)	41.9-47.8	622 (57.0)	53.9-59.8
Subway/train						
No	944 (86.8)	84.6-88.7	1,076 (100.0)	-	1,065 (98.7)	97.8-99.2
Yes	143 (13.2)	11.2-15.3	-	-	14 (1.3)	0.7-2.1
Car and/or taxi						
No	211 (19.1)	16.8-21.5	387 (35.7)	32.8-38.6	418 (38.1)	35.2-41.0
Yes	894 (80.9)	78.4-83.1	697 (64.3)	61.3-67.1	679 (61.9)	58.9-64.7
Motorcycle						
No	1,030 (94.1)	92.4-95.3	1,039 (96.1)	94.7-97.1	1,031 (95.5)	94.0-96.5
Yes	65 (5.9)	4.6-7.5	42 (3.9)	2.8-5.2	49 (4.5)	3.4-5.9

Note: There is no subway/train in Florianópolis. 95%CI: 95% Confidence Interval.

Source: Authors.

Table 2. Prevalence of self-reported depression according to covariates and modes of transport. Healthy Urban Mobility (HUM) Study, Brasília, Florianópolis, and Porto Alegre, Brazil, 2023.

Variable	Brasília			Florianópolis			Porto Alegre		
	%	95%CI	p[a]	%	95%CI	p[a]	%	95%CI	p[a]
Bicycle			0.013			0.010			0.001
No	17.1	14.4-20.1		17.6	15.2-20.2		20.7	18.1-23.5	
Yes	11.6	8.8-15.0		10.0	6.4-15.2		11.1	7.6-15.9	
Walking			0.104			0.685			0.926
No	11.2	7.4-16.5		15.7	12.3-19.6		18.5	14.2-23.7	
Yes	15.8	13.5-18.3		16.6	14.0-19.6		18.8	16.2-21.6	
Bus or van			0.657			0.365			0.484
No	14.5	11.8-17.6		17.2	14.4-20.5		19.6	16.3-23.5	
Yes	15.4	12.6-18.8		15.2	12.2-18.7		17.8	15.1-21.2	
Subway/train			0.091			-			0.780
No	14.3	12.2-16.6		-	-		18.5	16.3-20.9	
Yes	19.7	13.9-27.1		-	-		21.4	6.7-50.6	
Car or Taxi			0.178			0.776			0.615
No	11.9	8.2-17.1		16.7	13.3-20.8		17.8	14.4-21.9	
Yes	15.6	13.4-18.2		16.0	13.5-18.9		19.0	16.3-22.2	
Motorcycle			0.130			0.100			0.121
No	15.3	13.2-17.6		16.7	14.5-19.1		19.0	16.7-21.5	
Yes	8.2	3.4-18.3		7.1	2.2-20.2		10.2	4.2-22.5	

Note: There is no subway/train in Florianópolis. 95%CI: 95% Confidence Interval. [a] Pearson's Chi-square Test.

Source: Authors.

Table 3. Crude logistic regression analysis. Healthy Urban Mobility (HUM) Study, Brasília, Florianópolis, and Porto Alegre, Brazil, 2023.

Variable	Brasília		Florianópolis		Porto Alegre	
	Crude OR (95%CI)	p	Crude OR (95%CI)	p	Crude OR (95%CI)	p
Bicycle		0.014		0.011		0.001
No	Ref.		Ref.		Ref.	
Yes	0.63 (0.44-0.91)		0.51 (0.31-0.85)		0.47 (0.30-0.74)	
Walking		0.106		0.685		0.926
No	Ref.		Ref.		Ref.	
Yes	1.48 (0.91-2.39)		1.07 (0.76-1.50)		1.01 (0.70-1.46)	
Bus or van		0.657		0.366		0.484
No	Ref.		Ref.		Ref.	
Yes	1.07 (0.77-1.50)		0.85 (0.61-1.19)		0.89 (0.65-1.21)	
Subway/train		0.093		-		0.781
No	Ref.		-		Ref.	
Yes	1.47 (0.93-2.31)		-		1.20 (0.33-4.34)	
Car or Taxi		0.180		0.776		0.615
No	Ref.		Ref.		Ref.	
Yes	1.36 (0.86-2.15)		0.95 (0.68-1.33)		1.08 (0.78-1.49)	
Motorcycle		0.138		0.113		0.129
No	Ref.		Ref.		Ref.	
Yes	0.49 (0.19-1.25)		0.38 (0.11-1.25)		0.48 (0.18-1.23)	

Note: There is no subway/train in Florianópolis. 95%CI: 95% Confidence Interval.

Source: Authors.

Table 4. Adjusted regression analysis between self-reported depression and modes of transport. Healthy Urban Mobility Study (HUM), Florianópolis, Brasília, and Porto Alegre, Brazil, 2023.

Variable	Brasília		Florianópolis		Porto Alegre	
	Adjusted OR (95%CI)	p*	Adjusted OR (95%CI)	p*	Adjusted OR (95%CI)	p*
Bicycle		0.251		0.107		0.039
No	Ref.		Ref.		Ref.	
Yes	0.79 (0.53-1.17)		0.64 (0.37-1.09)		0.60 (0.37-0.97)	
Walking		0.058		0.730		0.620
No	Ref.		Ref.		Ref.	
Yes	1.61 (0.98-2.64)		1.06 (0.75-1.50)		1.09 (0.75-1.59)	
Bus or van		0.877		0.129		0.344
No	Ref.		Ref.		Ref.	
Yes	0.97 (0.67-1.39)		0.76 (0.54-1.08)		0.85 (0.62-1.18)	
Subway/train		0.044		-		0.411
No	Ref.		-		Ref.	
Yes	1.62 (1.01-2.62)		-		1.74 (0.46-6.64)	
Car or Taxi		0.173		0.463		0.376
No	Ref.		Ref.		Ref.	
Yes	1.39 (0.86-2.26)		1.14 (0.80-1.63)		1.16 (0.82-1.64)	
Motorcycle		0.558		0.570		0.355
No	Ref.		Ref.		Ref.	
Yes	0.72 (0.25-2.11)		0.69 (0.20-2.40)		0.63 (0.24-1.66)	

Note: There is no subway/train in Florianópolis. 95%CI: 95% Confidence Interval. *Adjusted for sex, age, education, and race/skin color.

Source: Authors.

Table 5. Adjusted regression analysis between self-reported depression and combinations of motorized and active modes of transport. Healthy Urban Mobility (HUM) Study, Brasília, Florianópolis, and Porto Alegre, Brazil, 2023.

Variable	Brasília		Florianópolis		Porto Alegre	
	Adjusted OR (95%CI)	p*	Adjusted OR (95%CI)	p*	Adjusted OR (95%CI)	p*
Motorized modes of transport						
Bus or van + Car or taxi	1.69 (0.72-3.99)	0.226	0.85 (0.51-1.43)	0.562	1.00 (0.59-1.68)	0.985
Bus or van + Subway/train	1.76 (1.03-3.01)	0.037	-	-	2.00 (0.50-8.07)	0.326
Bus or van + Motorcycle	1.10 (0.23-5.14)	0.903	-	-	0.81 (0.26-2.50)	0.718
Car or Taxi + Subway/train	2.19 (1.07-4.48)	0.031	-	-	0.76 (0.91-6.45)	0.808
Car or Taxi + Motorcycle	1.19 (0.37-3.80)	0.767	0.81 (0.17-3.77)	0.791	0.62 (0.17-2.17)	0.455
Subway/train + Motorcycle	1.71 (0.34-8.51)	0.511	-	-	-	-
Active modes of transport						
Bicycle + Walking	1.27 (0.68-2.40)	0.444	0.74 (0.39-1.38)	0.355	0.72 (0.40-1.27)	0.262

Note: There is no subway/train in Florianópolis. 95%CI: 95% Confidence Interval. *Adjusted for sex, age, education, and race/skin color.

Source: Authors.

Discussion

In this study, 16.6% of the total sample self-reported depression, and bicycle use was identified as a protective factor against self-reported depression across all cities, though it reached statistical significance only in Porto Alegre. On the other hand, the use of the subway/train increased the chances of self-reported depression in Brasilia. When analyzing the combined use of modes of transport, those who simultaneously rode bus/van and subway/train, and car/taxi

and subway/train, were more likely to report depression in Brasília.

The self-reported depression prevalence of 16.6% observed in our sample (15.0% in Brasília, 16.3% in Florianópolis, and 18.6% in Porto Alegre) is higher than the Brazilian national estimate of 10.2%[17], with expected variations across cities. Similarly, a 2020 study conducted in the United States found that 18.4% of adults (≥18 years) reported being diagnosed with depression, with prevalence rates ranging from 12.7% to 27.5% across different states[27]. In contrast, the point prevalence of clinically relevant depressive symptoms in Europe from 2018-2020 was 6.54%, with notable variation between countries, ranging from 1.85% in Greece to 10.72% in Sweden. Our findings suggest that the prevalence of depression in Brazilian urban areas, as reported in our study, is substantially higher than both the national average and European levels[28].

There is an increasing amount of evidence indicating that the modes of transport used by individuals can have a significant impact on their health and well-being, regardless of the reason for commuting[2,15,29]. In this study, the current use of bicycles was a protective factor for self-reported depression in Porto Alegre, which is in line with the findings of the international literature[2,30,31]. Corroborating our findings, a study conducted in Porto Alegre in 2019 showed that the time spent in transport per day increases perceived quality of life and well-being of cyclists and walkers[32].

There are several reasons why cycling can decrease the occurrence of depression. First, the practice of physical exercises has been associated with a variety of benefits, such as stress reduction[33], less work absence due to illness[34], well-being increase[31], more significant social interaction[35], and happiness[36]. Authors have pointed out that physical exercise produces antidepressant effects through multiple biological and psychosocial pathways[37].

A qualitative study conducted with individuals from 50 to 75 years old in Australia revealed additional aspects that are challenging to measure in epidemiological surveys. Participants pointed out that pleasure was a reason to engage in cycling. Also, cycling was considered an enjoyable way to spend time with family or make new friends, strengthening social networks. Respondents also associated cycling with positive expectations regarding the opportunity to be outdoors and with sense of freedom[38].

However, it is essential to understand that the link between cycling and depression is diverse, as several factors can influence the personal choice of cycling. A study in eight Latin American countries showed that positive perceptions of walking and cycling facilities were associated with greater physical activity[39]. In Florianópolis, a study highlighted that the distribution of bike lane structures is irregular between the regions of the city and has a low connection between the axles[40], posing substantial challenges to promoting active mobility across the city.

The positive perception of traffic and neighborhood safety is another aspect that provides a more conducive and encouraging environment for cycling[41,42], which can potentially reduce the risk of depressive symptoms and prevent other unfavorable health outcomes[35,43]. The indirect effects of cycling as a mode of transport are also mentioned. Research has revealed that increased use of bicycles and decreased dependence on automobiles reduce the emission of air pollution[44], which represents one of the greatest risk factors for lung pathologies[45].

Subway/train users were more likely to report depression in Brasilia. Also, when analyzing the simultaneous use of motorized modes, it was observed that people who use multiple modes of public transport (bus/van and subway/train) were more likely to report depression in the city. In fact, subway/train system in Brasília has several limitations, regarding extension and connectivity. It covers few regions of the city, and a small number of trains are available to passengers' transport[46]. In order to improve the quality of the service provided, the local government is analyzing the impacts of privatizing the subway system. However, privatization has been harshly criticized by the Legislative Chamber's Transport and Urban Mobility Committee, as the subway can stimulate the economic growing of specific neighborhoods of the city and serve some of their residents' transportation needs[47]. These findings corroborate the study developed by Jacob *et al.*[13] in the United Kingdom, in which the change from active travel mode to public transport was associated with a reduction in self-reported mental health, especially among men. The researchers highlighted that public transport users may have a sense of lack of control and passivity during the trip, due to overcrowding, impacting on mental health.

The 2022 Brazilian survey on Urban Mobility, conducted in Brazilian capitals, revealed that the fare value (68%), safety (52.7%), and comfort (50.3%) were the worst aspects according to public transport passengers (bus and subway).

Also, vehicle maintenance, punctuality of schedules, and complaint channels were pointed out as problem factors in the capitals[11]. In contrast, the free tax strategy increased public transport use among older adults in England by 8%, in addition to reducing depressive symptoms and feelings of loneliness by promoting social engagement[48]. Another study conducted in the United Kingdom showed that participants who reported a positive perception of public transport infrastructure were 1.29 times more likely to be frequent users (95%CI: 1.15-1.45), besides presenting better mental health outcomes[49]. These findings indicate the existence of strategies that improve the mental health outcomes of individuals who use public transport, emphasizing the need for infrastructure and safety investments.

For longer commuting, especially when there is no adequate infrastructure for cycling, it is crucial to encourage public transport use. To this end, measures such as the creation of accessible sidewalks, construction of bike lanes, and improvement of public transport infrastructure should be invested in, aiming to promote fairer and healthier environments[49]. However, the bicycle is positioned as one of the most democratic, economic, accessible and practical modes of transport, allowing individuals to enjoy the benefits of urban spaces in their entirety[50].

Concerning the simultaneous use of other transport modes, those who used car/taxi and subway/train showed the highest measure of effect in this research (OR: 2.19). The concomitant use of these modes can aggravate the mental health situation of individuals in Brasilia, probably due to the problems of the metro system mentioned before as well as the frequent problems faced by car users. Corroborating these findings, United States car passengers had significantly higher stress levels and negative mood levels[51]. They were associated with worse mental health status in Spain[14]. Our findings also corroborate the study developed by Avila-Palencia *et al.*[2], whose results showed that a higher frequency of car and public transport use was associated with poor self-perceived health. In other study, the use of public transport, such as subway or bus, was related to a 4.8% lower probability of depression compared to commuting in private vehicles[29]. In addition, high congestion is associated with stress and aggression, as evidenced in Toronto drivers[52], since drivers may perceive their trips as more laborious and unpredictable than public transport passengers[51].

Given our findings, it is important to strengthen public policies encouraging bicycle use as a sustainable commuting alternative in Brazilian cities. It is important to note that the specific characteristics of each municipality, such as spatial organization and climatic conditions, affect mobility behavior and, therefore, may have impacted the observed results. In the Brazilian context, replicating models from developed countries, which have milder climates and established infrastructure for active mobility, should be done with caution.

In light of these considerations, it is essential to consider the particularities of each municipality to promote a viable and safe incentive for the use of bicycles and other forms of active transportation. Data from the Mortality Information System (SIM) between 2010 and 2021 reveal an alarming statistic of 16,518 deaths of cyclists in Brazil, 294 of which occurred in Brasília, 70 in Porto Alegre, and 43 in Florianópolis[53]. These numbers demonstrate the urgence to ensure an adequate structure so that cyclists are not forced to share roads with cars in unsafe and high-speed conditions.

To face this challenge, Law No. 13,724/2018[54] was established in 2018, creating the Bicycle Brazil Program (PBB) to encourage the use of bicycles to improve urban mobility conditions. However, PBB must be comprehensively regulated to consolidate the National Urban Mobility Policy and emphasize the priority of non-motorized modes of transport over motorized ones. The focus of PBB should explicitly include the protection and safety of cyclists, not restricted to the establishment of safe intercity routes aimed at "tourism and leisure." It is crucial to consider that the bicycle is an essential mean of transport, including work and daily commuting.

When interpreting the results of this research, it is necessary to consider some aspects of the study. Due to the cross-sectional design, it is impossible to establish cause-and-effect relationships between the analyzed variables. Besides, self-reported depression may contain some limitations due to its subjective nature; however, it is widely used in Brazilian research, such as *Pesquisa Nacional de Saúde* (PNS) and *Vigilância de Fatores de Risco e Proteção para Doenças Crônicas por Inquérito Telefônico* (VIGITEL). Also, it was validated by other researchers, presenting satisfactory values of sensitivity (80.6%) and specificity (81.4%)[25]. Finally, it is noteworthy that the commuting time of individuals, in total or for each mode of transport, as well as car or motorcycle ownership information were not analyzed. However, it is essential to emphasize that, so far, our study is pioneering

in examining the relationship between the use of different modes of transport, in addition to simultaneous use, and its association with depression in Brazilian cities. For future research, it is suggested to investigate the time and purpose of the trip, in addition to investigating in more detail the integration between different modes of transport in daily routes.

It is concluded that there was an association between commuting by different modes of transport and self-reported depression, independent of sociodemographic factors. The bicycle, as an active mode of transport, proved to be a protective factor against depression in the city of Porto Alegre. In contrast, motorized modes of transport were identified as contributing to the increased likelihood of depression. Regular use of the bicycle as a mode of transportation can play an important role in promoting mental health. From a public health policy perspective, this highlights the necessity for city planning and transportation policies that prioritize infrastructure for cycling and active transport, considering the region's climate, topography, and other relevant factors to ensure these options are safe, accessible, and suitable for local conditions. For the healthcare system, integrating mental health promotion into urban mobility initiatives could help mitigate depression rates, especially in densely populated areas. These measures could contribute to a more holistic approach to public health.

Collaborations

D Hillesheim and E d'Orsi contributed to the study's conception and design, data analysis and interpretation, manuscript writing, and critical review and approved the final version. I Luiza Neto contributed to the manuscript writing and critical review and approved the final version. H Günther, JCB Vargas and T Jones contributed to the critical review of the study and approved the final version.

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Data availability statement

The data sources adopted in the research are indicated in the article's body.

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